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COAL-MINE EXPLOSIONS AND COAL- AND METAL-MINE FIRES IN THE UNITED STATES DURING THE FISCAL YEAR ENDED JUNE 30, 1947

BY

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COAL-MINE EXPLOSIONS AND COAL- AND METAL-MINE FIRES IN THE UNITED STATES DURING THE FISCAL YEAR ENDED JUNE 30, 1947[1]

By D. Harrington,[2] W. J. Fene,[3] and H. B. Humphrey[4]

In the fiscal years 1946 and 1947 the number of mine explosions decreased compared with the preceding years. However, the loss of life was so serious during the fiscal year 1947 - the period when the Government administered bituminous-coal and lignite mines - that from April to June 1947 extraordinary measures were taken in mines then under Government possession to obtain compliance with provisions concerning rock dusting, ventilation, and blasting that had not been followed. The great loss of life in explosions during the fiscal year 1947 as compared with 1944, 1945, and 1946 is not easy to explain, but the necessity for maintaining adequate protection has been definitely demonstrated. Management, workers, and inspection agencies alike must keep the mines reasonably safe against explosions or allow them to lapse into a condition where chance is the principal protection against disaster. The attention given to protecting coal mines and the men employed in them against mine fires, following the disastrous fires in 1944 and 1945, has at least temporarily controlled this hazard - loss of life from coal-mine fires was reduced to 1 fatality in 1947. The number of fires was also less, and progress has been made in reducing the heavy losses in both life and property from underground coal-mine fires that occurred in the two years mentioned.

Fatalities from mine explosions during the past 6 fiscal years, July 1942 to June 1947, totaled 674, and there were 149 explosions; during the preceding 6 years there were 655 fatalities in 132 explosions. The 6 fiscal years 1942-47 cover the active period of Federal coal-mine inspection. During the fiscal year 1947, there were 154 fatalities from explosions compared with 58 during the fiscal year 1946, 64 in 1945, 94 in 1944, 152 in 1943, and 152 in 1942.

SUMMARY OF MINE EXPLOSIONS, BY STATES AND CAUSES

Table 1 summarizes essential data on 17 coal-mine explosions in 8 States, which caused 154 deaths during the fiscal year ended June 30, 1947. It contains information on all coal-mine explosions during the fiscal year that were brought to the attention of the Bureau of Mines and is believed to cover every explosion in which life was lost or considerable damage was done. The 17 explosions in the past fiscal year were 4 fewer than the 21 reported during the previous fiscal year; the number of deaths was 96 more than in 1946, the year prior to Government operation.

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The 4 major explosions during the fiscal year 1947 resulted in 144 deaths; during 1946 there were 3 major explosions with 51 deaths and in 1945, 4 major explosions with 45 deaths. A major explosion is one in which 5 or more fatalities occur. Five of the 17 explosions known to have occurred during the past year did not result in fatalities; in 1946, 13 of the 21 reported explosions were without fatalities.

In 1947 one major disaster in Illinois causing 111 deaths and one in Indiana with 8 were caused by unsafe blasting practices, coupled with ineffective or no use of rock dust. Two major disasters in Pennsylvania anthracite mines resulted in 25 deaths; the primary cause in both was laxity in connection with methane. No explosions or ignitions were reported in bituminous-coal mines of Pennsylvania during the fiscal years 1946 and 1947. During 1947 1 explosion was reported as occurring in West Virginia; no fatalities resulted.

Table 2 summarizes the causes of explosions during the fiscal years 1929 to 1947 as determined from records of the Health and Safety Division of the Bureau of Mines. In the fiscal year 1947, 27 persons were killed in explosions initiated by electricity compared with 41 the year before and an average of 65.3 for the previous 10 years. During the fiscal year 1947, 2 explosions from electricity in Pennsylvania anthracite mines caused 25 deaths; 2 in Virginia 2 deaths; and 1 in Kentucky and 1 in Washington no deaths.

During the fiscal year 1947, 5 mine explosions were caused by open lights or smoking compared with 4 in the previous year and an average of 6.4 during the preceding 10 years. Explosions from this cause resulted in 4 deaths in the fiscal year 1947 compared with none in 1946 and an average of 19.7 over the previous 10 years. Alabama had 1 explosion with 2 deaths caused by open lights or smoking; Indiana had 2 explosions with 2 deaths; and Illinois and West Virginia 1 each with no deaths. In 2 ignitions gas was lighted by miners attempting to smoke; in 3 gas was ignited by carbide lights.

Six explosions, resulting in 123 deaths, were caused by unsafe blasting during the fiscal year 1947 compared with 6 explosions and 17 deaths in the year before and an average of 4 explosions from this cause and 20.4 deaths for the previous 10 years.

TABLE 1. - Summary of coal-mine explosions, by States and causes, fiscal year ended June 30, 1947

State	Lighting used			Fatalities, by causes of ignition									
				Electricity		Open lights or smoking		Explosives		Miscellaneous		Total	
	Open	Closed	Unknown	Deaths	Ignitions	Deaths	Ignitions	Deaths	Ignitions	Deaths	Ignitions	Deaths	Ignitions
Alabama	1	-	-	-	-	2	1	-	-	-	-	2	1
Illinois	1	1	-	-	-	-	1	111	1	-	-	111	2
Indiana	4	-	-	-	-	2	2	9	2	-	-	11	4
Kentucky	2	-	-	-	1	-	-	1	1	-	-	1	2
Pennsylvania	-	4	-	25	2	-	-	2	2	-	-	27	4
Virginia	-	2	-	2	2	-	-	-	-	-	-	2	2
Washington	-	1	-	-	1	-	-	-	-	-	-	-	1
West Virginia	-	1	-	-	-	-	-	-	-	-	-	-	1
Total	8	9	-	27	6	4	5	123	6	-	-	154	17

TABLE 2. - Summary of data on explosions, by causes, fiscal years 1929-47, inclusive

Year	Lighting used			Fatalities, by causes of ignition									
				Electricity		Open lights or smoking		Explosives		Miscellaneous or unknown		Total	
	Open	Closed	Unknown	Deaths	Ignitions	Deaths	Ignitions	Deaths	Ignitions	Deaths	Ignitions	Deaths	Ignitions
1929	17	19	1	93	18	14	10	26	8	6	1	139	37
1930	8	23	1	147	16	21	8	24	6	-	2	192	32
1931	12	13	-	131	8	56	11	18	6	-	-	205	25
1932	15	14	3	11	10	33	15	42	5	1	2	87	32
1933	6	14	1	25	8	63	7	29	4	5	2	122	21
1934	9	14	3	21	10	2	9	2	3	3	4	28	26
1935	5	17	-	29	10	6	8	3	2	16	2	54	22
1936	15	9	1	20	5	10	17	4	1	4	2	38	25
1937	4	12	4	53	12	3	5	-	1	6	2	62	20
1938	10	16	3	24	10	77	11	61	6	8	2	170	29
1939	2	12	-	13	9	2	3	-	-	1	2	16	14
1940	6	11	1	99	6	2	5	103	5	2	2	206	18
1941	5	21	-	145	14	15	9	3	3	-	-	163	26
1942	5	17	-	133	14	3	2	2	2	14	4	152	22
1943	11	17	4	66	19	86	9	-	3	-	1	152	32
1944	6	12	5	59	11	5	6	1	3	29	3	94	23
1945	6	26	2	20	13	4	8	17	11	23	2	64	34
1946	6	15	-	41	11	-	4	17	6	-	-	58	21
1947	8	9	-	27	6	4	5	123	6	-	-	154	17
Total	156	291	29	1,157	210	406	152	475	81	118	33	2,156	476

Table 3 shows the record of explosions, by States, for the past 19 fiscal years. During these 19 years, 476 mine explosions caused 2,156 deaths, an average of 25.05 explosions and 113.47 deaths per year. During the fiscal year 1947 the number of explosions (17) was lower than the average for the previous 19 years, and except for 1939, when 14 explosions were reported, is the lowest number of explosions reported in any fiscal year in the 19-year period. The number of fatalities resulting (154) was considerably higher than the average for the past 19 years and also much above the average for the years since 1940. For the 19-year period, Pennsylvania had the greatest number of explosions 127, with 353 deaths; West Virginia had 78 explosions, with 397 deaths; Ohio, with 17 explosions, had 209 deaths; and Illinois, with 22 explosions, had 197 killed. States that have not had a coal-mine explosion for exceptional lengths of time are Kansas, with none since 1929; Maryland, with none since 1932; and Wyoming, with the last reported in 1938. Washington has not reported a fatality from an explosion since 1940.

During the past 19 years, the average number of deaths per explosion has been 4.53. The lowest rate was 0.91 for Washington, the highest 74.00 for Montana. Other States with high averages were Ohio, 12.29; Illinois, 8.95; and Utah and Alaska, 7.00. Coal-producing States not shown in table 3, as they are not known to have had an explosion during the past 19 years, are Iowa, Michigan, Missouri, North Dakota, and Texas.

CAUSES OF EXPLOSIONS

Table 4 summarizes the data reported to the Bureau of Mines as to causes of explosions during the past 19 years. During that period 476 explosions were studied in all, an average of 25.1 explosions per year. The 17 explosions in the fiscal year 1947 were less by 4 than in the previous year and 8 less than the average for the preceding 18 years.

As shown in table 4, electricity caused the ignition of 210 (44.1 percent) of the explosions recorded during the past 19 years. Open lights and smoking were given as the cause of 152 (31.9 percent); hence, 76 percent of all known explosions during these 19 years were attributed to electricity, open lights, and smoking. In the 5 years from 1943 to 1947, 72.5 percent of the explosions were attributed to these causes, indicating that precautions against these hazards still were not having marked effect, although the reduction in the number of explosions from these causes in the last 2 years may indicate progress.

The number of explosions of electrical origin in the fiscal year 1947 (6) was about half the average number for the preceding 18 years (11.3). Explosions caused by open lights and smoking (5) were 3 fewer than the average for the previous 18 years (8.2); this reduction is not as great as might be expected because of the increasing use of closed lights in place of the open-flame type, indicating reluctance of at least some mining people to observe reasonable and readily feasible precautions for safeguarding of their own lives and property.

TABLE 3. - Record of explosions, by States, during fiscal years 1929-47, inclusive

	1929 to 1939		1940		1941		1942		1943		1944		1945		1946		1947		Total 19 years		Average per year		Average deaths per ignition
	Deaths	Ignitions	Deaths	Ignitions	Deaths	Ignitions	Deaths	Ignitions	Deaths	Ignitions	Deaths	Ignitions	Deaths	Ignitions	Deaths	Ignitions	Deaths	Ignitions	Deaths	Ignitions	Deaths	Ignitions	
Alabama	64	25	1	4	6	5	11	1	12	3	29	3	3	3	-	-	2	1	128	45	6.73	2.36	2.84
Alaska	14	1	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	14	2	.74	.11	7.00
Arkansas	9	5	3	1	10	1	8	2	5	4	6	4	-	-	-	-	-	-	41	17	2.15	.90	2.41
Colorado	18	8	1	1	2	1	34	2	3	1	1	2	-	-	-	1	-	-	59	16	3.11	.84	3.69
Illinois	75	13	1	1	-	1	8	1	1	2	-	-	1	1	-	1	111	2	197	22	10.37	1.16	8.95
Indiana	56.	8	-	-	16	3	-	-	-	1	-	-	1	2	-	-	11	4	84	18	4.42	.95	4.66
Kansas	2	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1	.11	.05	2.00
Kentucky	67	13	28	1	-	-	16	2	10	4	14	2	5	6	24	3	1	2	165	33	8.68	1.74	5.00
Maryland	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	.05	.05	1.00
Montana	-	-	-	-	-	-	-	-	74	1	-	-	-	-	-	-	-	-	74	1	3.90	.05	74.00
New Mexico ..	22	4	-	-	-	-	-	-	-	-	-	-	6	1	-	-	-	-	28	5	1.47	.26	5.60
Ohio	93	10	72	1	32	2	-	-	7	3	-	-	-	1	-	-	-	-	209	17	11.00	.90	12.29
Oklahoma	127	13	2	1	1	1	5	2	7	3	-	1	10	2	-	-	-	-	152	23	8.00	1.21	6.61
Pennsylvania.	220	86	-	2	76	5	5	5	1	4	15	6	5	11	4	4	27	4	353	127	18.58	6.68	2.77
Tennessee ...	-	4	1	1	1	2	-	2	10	1	1	1	-	-	1	1	-	-	14	12	.74	.63	1.16
Utah	31	5	-	-	1	1	-	-	-	-	-	-	31	3	-	-	-	-	63	9	3.32	.47	7.00
Virginia	128	14	1	1	-	-	-	-	-	1	-	-	2	2	13	4	2	2	146	24	7.68	1.26	6.08
Washington ..	20	16	1	2	-	-	-	1	-	-	-	-	-	1	-	2	-	1	21	23	1.11	1.21	.91
West Virginia	153	54	95	2	18	4	65	4	22	4	28	3	-	1	16	5	-	1	397	78	20.89	4.11	5.09
Wyoming	8	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8	2	.42	.11	4.00
Total ..	1113	283	206	18	163	26	152	22	152	32	94	23	64	34	58	21	154	17	2156	476	113.47	25.05	4.53

TABLE 4. - Comparison of explosions by causes of ignition, fiscal years 1929-47

Year	Ignition by electricity		Ignition by open lights or smoking		Ignition by explosives		Ignition due to unknown or miscellaneous causes		Total	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
1929	18	48.7	10	27.0	8	21.6	1	2.7	37	100
1930	16	50.0	8	25.0	6	18.8	2	6.2	32	100
1931	8	32.0	11	44.0	6	24.0	-	-	25	100
1932	10	31.3	15	46.9	5	15.6	2	6.2	32	100
1933	8	38.1	7	33.3	4	19.1	2	9.5	21	100
1934	10	38.5	9	34.6	3	11.5	4	15.4	26	100
1935	10	45.4	8	36.4	2	9.1	2	9.1	22	100
1936	5	20.0	17	68.0	1	4.0	2	8.0	25	100
1937	12	60.0	5	25.0	1	5.0	2	10.0	20	100
1938	10	34.5	11	37.9	6	20.7	2	6.9	29	100
1939	9	64.3	3	21.4	-	-	2	14.3	14	100
1940	6	33.3	5	27.8	5	27.8	2	11.1	18	100
1941	14	53.8	9	34.6	3	11.6	-	-	26	100
1942	14	63.6	2	9.1	2	9.1	4	18.2	22	100
1943	19	59.4	9	28.1	3	9.4	1	3.1	32	100
1944	11	47.9	6	26.1	3	13.0	3	13.0	23	100
1945	13	38.2	8	23.5	11	32.4	2	5.9	34	100
1946	11	52.4	4	19.0	6	28.6	-	-	21	100
1947	6	35.3	5	29.4	6	35.3	-	-	17	100
Total	210	44.1	152	31.9	81	17.0	33	7.0	476	100
Average	11.1	44.1	8.0	31.9	4.3	17.0	1.7	7.0	25.1	100

Table 4 shows that 6 explosions were caused by unsafe use of explosives during the past year, compared with 6 in the preceding year and an average of 4.2 for the previous 18 years. The number of explosions from this cause has been increasing in the past 10 years, leading to the conclusion that the use of explosives in many coal mines does not follow readily available safe procedures.

Although definite proof of the exact cause of one or two explosions occurring during the past year was not conclusive, evidence of the probable cause was thought to be enough to warrant classification under the causes assigned.

EXPLOSION FATALITIES, BY CAUSES

Explosion fatalities are compared by causes in table 5, showing that, in the past 19 years, 2,156 fatalities have resulted from mine explosions in the United States, an average of 113.5 a year. The number of explosion fatalities recorded for the fiscal year 1947 (154) was 96 more than for the year before and 43 more than the average for the preceding 18-year period (111.2). Four major explosions in 1947 resulted in 144 deaths and 13 minor explosions in 10 deaths, compared with the record for the fiscal year 1946, when 3 major explosions occurred, with 51 deaths and 18 minor explosions with 7 deaths.

Explosions of electrical origin caused 27 (17.5 percent) deaths in 1947, a marked decrease from the 41 deaths from this cause in 1946 and from the average of 62.8 for the previous 18 years. The reduction in the number of explosions of electrical origin and in the fatalities from this cause since 1943 may indicate that the hazards of electrical equipment in gassy mines are being more widely recognized and that the use of such equipment is being safeguarded with better effect than previously. While there is evidence both from the record and in the field that improvement is being made, there is still great danger from this source, which in the last 2 years caused about 44 percent of the explosions and 44 percent of explosion fatalities. Certainly the hazard from electricity is so great as to warrant the use of only the safest types of electrical equipment and the safest procedures.

Explosions from open lights and smoking caused 4 deaths in the past fiscal year, while there were no deaths from this cause in the fiscal year 1946. This is an encouraging decrease in this type of explosion and in the fatalities resulting, which over the previous 18 years amounted to about 20 percent of all deaths from explosions. The rapid replacement of open lights by permissible cap lamps and the growing acceptance of restrictions against smoking in coal mines have begun to limit this hazard. The practice of smoking, with or without restrictions against the practice, has not been eliminated from either anthracite or bituminous-coal mines, large or small, and it is possible that several explosions that have been attributed to electrical origin where both sources of ignition were present were really due to smoking. During the fiscal year 1947 2 explosions of gas ignited by open lights caused 4 deaths, and 1 other caused severe burns to 3 miners but no deaths. Smoking was known to have caused 2 ignitions of gas, causing injuries to 4 persons. There may have been other such incidents not reported to the Bureau and smoking is a possible cause of some major disasters in the last few years, even though other causes were considered more probable. Both of these sources of explosions - open lights and smoking - should be excluded from coal mines; they are in no way essential to operation of the mine and are remnants of outmoded and definitely hazardous practices.

TABLE 5. - Comparison of explosion fatalities, by causes of ignition, fiscal years 1929-47, inclusive

Year	Ignition by electricity		Ignition by open lights or smoking		Ignition by explosives		Ignition due to unknown or miscellaneous causes		Total	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
1929	93	66.9	14	10.1	26	18.7	6	4.3	139	100
1930	147	76.6	21	10.9	24	12.5	-	-	192	100
1931	131	63.9	56	27.3	18	8.8	-	-	205	100
1932	11	12.7	33	37.9	42	48.3	1	1.1	87	100
1933	25	20.5	63	51.6	29	23.8	5	4.1	122	100
1934	21	75.0	2	7.1	2	7.1	3	10.8	28	100
1935	29	53.7	6	11.1	3	5.6	16	29.6	54	100
1936	20	52.6	10	26.4	4	10.5	4	10.5	38	100
1937	53	85.5	3	4.8	-	-	6	9.7	62	100
1938	24	14.1	77	45.3	61	35.9	8	4.7	170	100
1939	13	81.3	2	12.5	-	-	1	6.2	16	100
1940	99	48.3	2	1.0	103	49.7	2	1.0	206	100
1941	145	89.0	15	9.1	3	1.9	-	-	163	100
1942	133	87.5	3	2.0	2	1.3	14	9.2	152	100
1943	66	43.4	86	56.6	-	-	-	-	152	100
1944	59	62.8	5	5.3	1	1.1	29	30.8	94	100
1945	20	31.3	4	6.2	17	26.6	23	35.9	64	100
1946	41	70.7	-	-	17	29.3	-	-	58	100
1947	27	17.5	4	2.6	123	79.9	-	-	154	100
Total	1157	53.7	406	18.8	475	22.0	118	5.5	2156	100
Average	60.9	53.7	21.4	18.8	25.0	22.0	6.2	5.5	113.5	100

Explosions resulting from unsafe use of explosives caused 123 deaths in the past year and a total of 475 deaths in the past 19 years. The marked increase in the number of explosions from this cause during the last 3 years and the loss of life resulting from these explosions clearly indicate the hazard now existing from the blasting practices used by far too many coal mines. During the fiscal year 1947, 6 explosions with 123 deaths resulted from this cause; since 1940, 39 explosions caused by explosives resulted in 266 deaths; from 1929 to 1939, there were 42 such explosions with 209 deaths. It is not indicated that the situation is improving in late years; rather the opposite, even though permissible explosives and other precautions are used in more mines each year. Three explosions in 1947, resulting in 9 deaths, were in bituminous-coal mines where black powder was used; 2 explosions in anthracite mines caused 2 fatalities when gas was ignited during blasting. A major disaster causing the loss of 111 lives was caused by unsafe blasting in a mine that used permissible explosives though in anything but a permissible manner and also used rock-dusting in anything but an adequate amount or extent. The conclusion of the investigating committee regarding the hazard from explosives was: "Permissible explosives, charged and fired in a permissible manner, are safe explosives. Permissible explosives stemmed with coal dust and fired with fuse in a dependent sequence are dangerous. The maximum safety will be obtained, however, when all shots are fired in a permissible manner while all men except the shot firers are out of the mine."

CAUSES OF EXPLOSIONS OF ELECTRICAL ORIGIN

The information available to the Bureau of Mines on causes of explosions of electrical origin in the United States for the past 19 years is shown in table 6. During this period at least 210 explosions from this cause are known to have occurred, resulting in 1,157 fatalities, of which 6, with 27 fatalities, occurred during the past fiscal year.

Trolley or cable-reel locomotives and nonpermissible mining machines jointly were responsible for 47 percent of the explosions of electrical origin during the 19-year period and for 63 percent in 1946, although none are reported to have resulted from this cause in the fiscal year 1947.

During the past year electric arcs, in which "nipping" is included, caused 2 explosions and "shorted" cables, electric drills, storage-battery locomotives, and electric hoists, 1 each. Coal-mine explosions of electrical origin during the past year were marked with the same carelessness and disregard of fundamental and simple safety practices as in those of the previous 18 years. Included are: (1) Failure to test for gas before electrical equipment is taken into working places in gassy mines or failure to test from time to time during its operation; (2) use of electrical equipment too soon after the fan has been started after a shut-down; (3) failure to examine a mine properly on days when only a small crew is working; (4) use of haulageways as return airways; (5) failure to install permissible electric equipment; and other careless practices involving use of electric equipment without due regard for adequate ventilation at all times.

TABLE 6. - Electrical causes of explosions, fiscal years 1929-47, inclusive

Type of equipment	1929 to 1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	Total 19 years	Number killed 1946	Number killed 1947
Nonpermissible equipment														
Trolley or cable-reel locomotive	29	4	3	-	3	1	-	5	2	5	-	52	5	-
Mining machine	22	3	-	2	4	2	4	3	4	2	-	46	24	-
Electric motor	9	1	2	-	1	-	2	1	1	-	-	17	-	-
Shotfiring battery or circuit	3	-	-	-	-	-	-	-	-	-	-	3	-	-
Cable nips or blown-out cable	4	-	1	-	1	-	1	-	2	2	1	12	-	-
Electric drill	5	-	2	2	3	1	5	1	1	-	1	21	-	-
Storage battery locomotive	2	-	-	-	-	-	-	-	1	1	1	5	12	1
Electric hoist	1	-	-	-	-	-	-	-	-	-	[3]1	2	-	10
Faulty wiring	4	-	-	-	-	-	-	-	-	-	-	4	-	-
Trolley wire	5	-	-	-	1	2	-	-	-	-	-	8	-	-
Electric arc	11	2	1	2	1	8	7	1	2	1	[3]2	38	-	15
Signal wire	2	-	-	-	-	-	-	-	-	-	-	2	-	-
Total	[1][2]97	10	9	6	14	14	19	11	13	11	6	210	41	27

[1] 1 explosion possibly due to a trolley locomotive and 1 possibly due to a nonpermissible mining machine arc not included in this total.

[2] 2 explosions possibly due to nonpermissible shot-firing units or circuits not included in this total.

[3] Included, but may have been from smoking.

The average number of explosions of electrical origin in 1935-40 was 8.6 per year; from 1941-46 it was 13.6; and in the past fiscal year, 6. Greater care in providing and maintaining efficient ventilation, testing for gas, and restricting the installation and use of nonpermissible electric equipment are and will continue to be necessary to prevent explosions from this cause. The use of electricity continues to be the greatest hazard as to initiating fires and explosions in the coal mines of the United States, and the very least that should be done is to use the safest available equipment, with procedures as to installation, maintenance, and use the safest known.

COMPARISON OF LIGHTING IN MINES WHERE EXPLOSIONS OCCURRED

Table 7 shows the method of lighting used in mines where explosions occurred during the past 19 years. During these years there were 476 explosions, of which 157 (33.0 percent) were in open-light mines, 290 (60.9 percent) were in closed-light mines, and 29 (6.1 percent) in mines in which the lighting practice was not reported. During the fiscal year 1947, 8 (47.1 percent) occurred in open-light mines compared with an average of 7.7 for the previous 18 years and an average of 6.8 for the preceding 5 years.

In the past year 52.9 percent of the explosions occurred in closed-light mines compared with 61.2 percent for the preceding 18 years. The percentages of explosions occurring in open- and in closed-light mines in each year varies widely, but the averages over the period indicate the general ratio. There is no trend or change indicated in this ratio, so far. There are fewer open-light mines each year, and the likelihood of explosions in closed-light mines is less than in mines continuing to use open lights. Hence, the ratio of explosions in the two types of mines may remain fairly constant, although the total number should, by all means, be reduced. Most of the gassy mines use closed lights; but some do not exercise corresponding care to eliminate other sources of ignition, such as use of permissible electrical equipment and elimination of smoking, or to maintain constant and adequate ventilation. In the open-light mines gas is very likely to be a potential hazard even though the mine is considered nongassy. In 1946 and 1947, 6 of the explosions in open-light mines designated as nongassy or slightly gassy were caused by the open lights, 5 were caused by explosives, 2 by electricity, and 1 by smoking in a mine using both open and closed lights. Most of these mines were small and altogether employed only a few men. The principal risk to life is in the mines using closed lights but neglecting ventilation, tests for gas, and other precautionary measures. Among the dangerous practices still followed in some mines known to give off explosive gas and placed on a closed-light basis is the use of open-type electrical equipment (pumps, drills, cutting machines, loading machines, conveyor motors, and locomotives) in parts of the mine not constantly ventilated by moving currents of fresh air. Often explosions are due to conditions brought about by the use of blower-fan systems of ventilation. One of the most frequent dangers is the practice of smoking in closed-light mines, either with silent consent of management and men or in direct violation of company rules, or State laws or regulations. Another disregard of the safe practice that was primarily responsible for several explosions in the fiscal years 1946 and 1947 was the failure to make regular and special tests for gas in face workings or in haulageways ventilated with air returning from face workings. These lapses have occurred in mines operated by long-established companies regarded as having efficient and competent management; in many cases unsafe installations and procedures have been used without accident for many years, but ultimately the law of averages prevails and a disaster occurs.

TABLE 7. - Summary of lighting in mines where explosions occurred, fiscal years 1929-47, inclusive

Year	Open lights		Closed lights		Lighting unknown		Total	
	Explosions	Percent	Explosions	Percent	Explosions	Percent	Explosions	Percent
1929	17	45.9	19	51.4	1	2.7	37	100
1930	8	25.0	23	71.9	1	3.1	32	100
1931	12	48.0	13	52.0	-	-	25	100
1932	15	46.9	14	43.7	3	9.4	32	100
1933	7	33.3	13	61.9	1	4.8	21	100
1934	9	34.6	14	53.9	3	11.5	26	100
1935	5	26.1	17	73.9	-	-	22	100
1936	15	60.0	9	36.0	1	4.0	25	100
1937	4	20.0	12	60.0	4	20.0	20	100
1938	10	34.5	16	55.2	3	10.3	29	100
1939	2	14.3	12	85.7	-	-	14	100
1940	6	33.3	11	61.1	1	5.6	18	100
1941	5	19.2	21	80.8	-	-	26	100
1942	5	22.7	17	77.3	-	-	22	100
1943	11	34.4	17	53.1	4	12.5	32	100
1944	6	26.1	12	52.2	5	26.1	23	100
1945	6	17.6	26	76.5	2	5.9	34	100
1946	6	28.6	15	71.4	-	-	21	100
1947	8	47.1	9	52.9	-	-	17	100
Total	157	33.0	290	60.9	29	6.1	476	100

EXPLOSIONS IN BITUMINOUS-COAL MINES

Figure 1 shows the trend of fatalities resulting from gas and dust explosions in bituminous-coal mines of the United States during the calendar years 1906 to 1946, inclusive. The figures for 1945 and 1946 are preliminary and subject to final revision. The trend of explosion fatalities was downward from 1907 to 1921, with a marked rise from 1921 to 1924 and a definite and relatively steady decline from 1924 to 1935. An upward trend from 1936 to 1943, with especially high fatalities in 1940 and 1943, dropped in 1944 and 1946 to what may be regarded as the average low record of 30 deaths. The lowest annual records have been 27 in 1933, 26 in 1935, 34 in 1943, and 30 in 1946. Fatalities for the first half of 1947 numbered 124. In every alternate year from 1924 to 1936, the number of deaths increased over that of the preceding year, although the general trend was downward. A plausible explanation of this is that following a year in which relatively low explosion-fatality occurrence is experienced, efforts to prevent explosions are relaxed; on the other hand, a year with a high explosion-fatality record may have caused additional measures of precaution to be taken. This tendency is not as clearly apparent in the period since 1935; changes in mining methods and practices have been more rapid than formerly, and other factors may have affected the trend. As was mentioned, the important fact is that the explosion hazard is still far from being under absolute control in coal mines, anthracite and bituminous.

The trend of explosion fatalities is illustrated in another way by the tabulation on the graph of the average annual fatalities for 5-year periods from 1906-10 to 1941-45. A large decrease in average annual fatalities from 438 for the period 1906-10 to 176 for the period 1916-20 was followed by a rise to 296 for the 5-year period 1921-25, which dropped to 65 for 1931-35, followed by 116 for 1936-40 and 102 for 1941-45. The good record for 1931-35 gave hope that disastrous mine explosions in the United States had been eliminated to a great extent, but the record for the next 5 years proved this hope unfounded, as was also shown by the average of 102 for 1941-45. The average fatalities from explosions in bituminous-coal mines can be brought below 50, possibly below 30, a year and that record maintained at any time the mine operators, the miners, and those in authority over enforcement of safety conditions in mines, determine that obvious explosion hazards will not be permitted in mines in which coal is being produced. This condition cannot be accomplished by any one of the above groups but is possible by cooperation between them, the only stipulation being that half-way measures are only slightly more effective than none.

Hazards that have contributed to the explosions of recent years are: (1) Failure to test for gas before and during work in face regions in mines where gas is known to be liberated, (2) use of open-type electric equipment without the provision of constant ventilation to prevent accumulation of explosive mixtures, (3) unsafe methods of blasting including the use of nonpermissible explosives, (4) failure to allay dust at its source or to remove dust accumulations, and (5) inadequate rock dusting, (6) failure to stop smoking in mines, failure to eliminate the use of open lights, black powder, fuse and caps, disregard of ventilation adjuncts such as leaving doors open, etc.

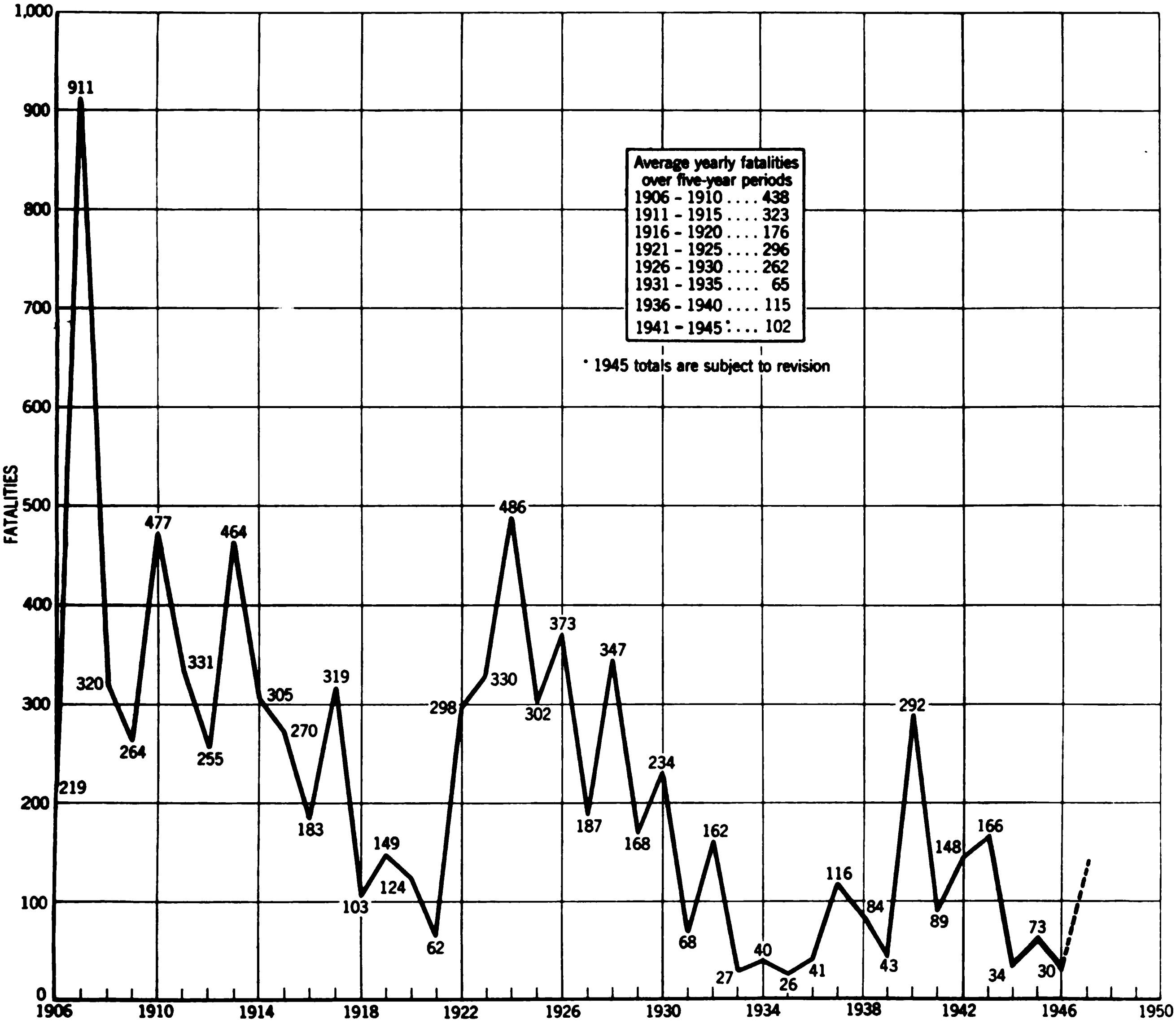

Figure I. - Fatalities from gas- and coal-dust-explosion in bituminous coal mines.

Explosion prevention in coal mines depends fully as much on the workers as on the management and unless both do their part in trying to prevent explosions, disasters are certain to continue to occur.

MINE FIRES

During the fiscal year 1947, 16 coal-mine fires and 2 metal-mine fires were reported to the Bureau of Mines. No deaths resulted from these fires, and only 1 death was caused by a mine fire in 1946, when a timberman fighting a fire was affected by gases and attempted to go alone to the outside in an electric locomotive; he was overcome on the way and fell under the locomotive. The record of mine fires summarized in table 8 shows this to be the first year since 1930 in which no deaths were reported from this cause. It is very evident that the toll of life from coal-mine fires in the preceding 4 years, 115 altogether, caused the taking of protective measures that should be continued and improved to save both lives and property. The number of fires in each of the past 2 years has been much below the average of the previous 4 years (29). The property and production losses were much smaller in 1946-47 than in the 4 preceding years; in fact, no serious fires have occurred in coal-mines in the past 2 years. In metal mines 2 serious fires caused relatively heavy loss of property but no loss of life.

Table 8 shows that, of the coal-mine fires in the fiscal year 1947, 6 were reported in Pennsylvania, 2 each in Kentucky, Washington, and West Virginia, and 1 each in Alabama, Illinois, Montana, and Ohio. In addition, there were reports of several return visits of Bureau personnel to assist in controlling fires reported in previous years. Neglect to effectively control and extinguish mine fires creates widespread hazard to lives and property; the danger or probable loss in many instances may appear unimportant at the time the fire is discovered or is thought to be isolated, but often these neglected or latent fires later result in abandonment of areas that might have otherwise been mined at a profit or necessitate heavy expense in attempts to control or extinguish them. The solution of this problem calls for better organization of private, State, and Federal agencies to provide cooperation and concerted action in dealing with fires which are not promptly extinguished.

Several surface fires, some of which destroyed tipples, storage bins, or mills, were reported but are not included in table 8, as the fire did not extend to the mine workings. In the past year, 2 metal-mine fires are recorded, both of which resulted in burning out the shaft and closing the mine. One fire was started by hot metal falling into a shaft from cutting operations at the collar, and the other started in the hoist room when gasoline vapors were ignited during the filling of an engine tank; no lives were lost.

Of the 16 fires in coal mines during the fiscal year 1947, 5 were of electrical origin, 1 was the result of unsafe use of explosives, 1 from smoking, 1 from an open light, 3 from spontaneous combustion, 2 from surface fires, 1 from friction of a conveyor belt, 1 from hot metal dropping down a shaft while cutting rails at the mouth of the shaft, and 1 from an old fire that rekindled.

TABLE 8. - Summary of mine fires, by States, fiscal years 1947 and 1930-46, inclusive

State	Lighting used			Fatalities, by cause of ignition									
				Electricity		Open lights		Explosives		Unknown or miscellaneous		Total	
	Open	Closed	Unknown	Deaths	Fires	Deaths	Fires	Deaths	Fires	Deaths	Fires	Deaths	Fires
Alabama	1	-	-	-	1	-	-	-	-	-	-	-	1
Colorado	1	-	-	-	-	-	1	-	-	-	-	-	1 (met.)
Illinois	1	-	-	-	-	-	1	-	-	-	-	-	1
Kentucky	2	1	-	-	1	-	1	-	-	-	1	-	3 (1 met
Montana	1	-	-	-	-	-	-	-	-	-	1	-	1
Ohio	-	1	-	-	-	-	-	-	-	-	1	-	1
Pennsylvania	-	[1]5	1	-	2	-	-	-	1	-	3	-	6
Washington	2	-	-	-	-	-	-	-	-	-	2	-	2
West Virginia	-	2	-	-	1	-	-	-	-	-	1	-	2
Total 1947	8	9	1	-	5	-	3	-	1	-	9	-	18
1946	7	15	1	-	9	-	1	1	5	-	8	1	23
1945	9	26	2	69	22	1	3	-	5	1	7	71	37
1944	2	10	20	6	12	-	-	-	3	2	17	8	32
1943	8	7	12	13	6	-	-	-	1	2	20	15	27
1942	10	7	9	4	9	-	2	-	1	17	14	21	26
1941	3	8	5	2	7	-	-	-	3	-	6	2	16
1940	12	9	6	2	5	-	2	-	1	-	19	2	27
1939	9	9	2	1	8	-	1	-	3	2	8	3	20
1938	7	6	11	1	7	2	2	-	1	5	14	8	24
1937	7	4	10	9	5	-	-	-	3	2	13	11	21
1936	16	4	3	1	7	-	2	-	3	3	11	4	23
1935	7	5	14	11	11	-	1	-	-	-	14	11	26
1934	10	5	3	-	4	-	-	5	5	1	9	6	18
1933	12	6	9	-	7	-	-	-	2	2	18	2	27
1932	8	5	8	1	8	-	-	-	3	-	10	-	21
1931	12	7	5	-	7	5	3	-	5	18	9	23	24
1930	7	8	9	2	9	3	6	-	3	-	6	5	24
Total, 18 years	154	150	130	122	148	11	26	6	48	55	212	194	[2]434

[1] 1 Outcrop fire, burning for several years.
[2] Includes 66 metal-mine fires and 15 outcrop fires.

The indicated hazards causing mine fires are slipshod practices in installing, using, and maintaining electric equipment, spontaneous combustion in certain coal fields, careless use of cutting torches, use of open lights, smoking, and the use of black powder and fuse. One of the main sources of coal-mine fires is the trolley-locomotive system, including both the locomotive and the trolley wires. Undoubtedly progress is being made in reducing fire hazards in a considerable number of mines; but available reports on mines, coal and noncoal, show them to be present in many others.

SUMMARY

1. Disasters from fires and explosions in coal mines during recent years have emphasized the need for better protection by management, mine employees, and State, Federal, and other agencies charged with improving mine safety. Because of these disasters, efforts to reduce the contributory hazards have been more active and direct, and some improvements are evident. From 1921 to 1941, there were 6 major disasters from coal-mine fires, resulting in 42 deaths. During the fiscal years 1942-45 there were 5 such disasters causing 100 deaths. In 1946-47 there was only 1 death from a mine fire.

When preparations are not made to take care of an underground fire emergency, coal-mine fires may endanger not only the men in the mine but those who enter to attempt to subdue the fire. Every underground mine (coal or noncoal) has fire hazards, and every mine should be provided with ample fire-fighting equipment and material placed at strategic places in the mine. Moreover, all persons at the mine should be instructed in the best procedure to follow in case of fire. Instructions should be given to all employees as to suitable procedures to be used by entrapped men to seal themselves off at favorable places if initial efforts to extinguish a fire or to remove the men are unsuccessful. Obviously, it is of first importance to keep procedures and precautions in effect at all times to prevent fires from starting.

2. The increase in both frequency and severity of mine explosions in the United States in the fiscal years 1940-43, after a prolonged downward trend, was followed in 1944-47 by a series of explosion disasters that kept the toll of life high although the number of explosions was less. A slight improvement in the record for 1944-46 was reversed by a total of 144 deaths from 4 major explosions in January-April 1947. The measures taken as a consequence of these disasters removed numerous hazardous conditions found in many of the coal mines throughout the country; and if the known procedure as to ventilation, rock dusting, blasting, installation and use of electrical equipment and inspection for gas are maintained to a reasonable degree the occurrence of explosions and the number of men killed by them should be reduced, even though it is improbable that they will ever be eliminated.

3. The number of explosions from electrical causes was reduced in 1947. The record for the previous 6 years indicated that little if any progress was being made in the adoption of suitable precautions in the use of electric equipment and in securing types of equipment fitted to mine conditions. Whether the reduction in explosions of electrical origin in 1947 is an indication of real improvement remains to be seen, and there is reason to believe that it is only temporary because innumerable unsafe types of electrical

equipment and procedures in connection with the equipment remain in our coal mines.

Some significant points brought out by the Bureau of Mines study of explosions and fires in the United States during the fiscal year 1947 are:

1. Seventeen coal-mine explosions, 5 of which were in anthracite mines (4 in Pennsylvania and 1 in Virginia), were studied as compared to 21 explosions in 1946 and an average of 25.9 explosions a year during the previous 18 years. This was a decrease of 19.1 percent from the previous year and a decrease of 34.4 percent compared with the average for the preceding 18 years.

2. Coal-mine explosions resulted in the loss of 154 lives during the fiscal year 1947, compared with 58 in 1946 and an average of 111.2 in the previous 18 years. This is an increase of 167 percent over 1946 and of 39 percent from the average of the previous 18 years. The anthracite mines of Pennsylvania reported 4 explosions during the fiscal year, 2 resulting in a total of 25 deaths and 2 causing 1 fatality each.

3. The 4 major explosions in the fiscal year 1947 resulted in 144 deaths, compared with 3 major explosions in 1946 causing 51 deaths. Of the 4 major explosions in 1947, 1 occurred in a mechanized bituminous-coal mine and 1 in a mine using hand-loading methods in which coal was not undercut and black powder was used. Some rock had been applied in 1 mine. The other 2 major explosions were in anthracite mines. Had the 2 bituminous-coal mines been rock-dusted according to recommended standards, it is probable that the disasters would not have occurred, as the explosions would have been confined so that but few lives would have been endangered. Operation of any bituminous-coal mine without adequate rock dusting at all times should not be countenanced.

During the year 5 explosions were reported in which no deaths resulted, although at least 12 persons were burned or otherwise injured.

4. Eight explosions occurred in open-light mines, compared with 6 in 1946 and an average of 8.2 in the preceding 18 years; 9 occurred in closed-light mines, as against 15 in 1946 and an average of 15.7 in the preceding 18 years. In the fiscal year 1947, two explosions were known to have been caused by smoking, and smoking was suspected as a possible cause of others that have been attributed to electric arcs, both hazards being present. For this year, at least, flame safety lamps were not known to have been a cause of an explosion.

Two explosions with no deaths were reported to have been caused by smoking; 3 explosions with 4 deaths were caused by open lights in mines where gas was thought not to be dangerous or where the danger was ignored. In none of these cases was an attempt made to test for the presence of gas before open lights were taken in.

5. Six explosions, causing 27 deaths, were of electrical origin, compared with 11 such explosions and 41 deaths in the previous year and an average of 11.3 explosions and 63 deaths annually for the preceding 18 years. The use of

electricity in mining operations continues to increase, and it is evident that the practices of many operators in the installation and use of such equipment are not suitable or sufficient for protection against the hazards created. Certainly, due regard is not given to even the restrictions for use of tested and approved types exclusively in gassy mines and observance of established safe standards for use and maintenance. The use of nonpermissible equipment where gas and dust accumulations are not carefully controlled deliberately ignores the possibility of an explosion. The hazards due to use of electricity in coal mines are so numerous and so great that only the safest available equipment, installations, and procedures should be used.

6. Six explosions, with 123 deaths, were caused by explosives during the fiscal year, compared with 6 explosions and 17 deaths in 1946 and an average of 4.2 explosions and 19.6 deaths annually in the preceding 18 years. The large increase in the number of explosions from the use of explosives and the heavy loss of life from them in 1945, 1946, and 1947, compared with the favorable record of the preceding 4 years, indicate that unsafe explosives and blasting practices have been prevalent in recent years, even though permissible explosives are being used in greater quantities and in more mines. The use of black blasting powder or dynamite in coal mines is contrary to established safe mining practice; and unless it is eliminated it will continue to cause explosions, fires, and other accidents resulting in death, injury, and loss of property. Careless and unsafe use of permissible explosives is a hazard that must be curbed if disasters due to explosives are to be eliminated, The record of the past year has emphasized the fact that taking short cuts in blasting or continued reliance on old or traditional methods of blasting in coal mines is certain to bring death to those failing to adopt readily available and feasible safe and sensible procedures. Permissible explosives are relatively safe if used in accordance with procedures that are or should be well-known to mining people; however, unless used in accordance with known safety procedures, they are anything but safe and can cause disasters.

7. Of the 17 explosions reported as occurring during the fiscal year 1947, 12 are thought to have been initiated by ignitions of gas and 5 by ignition of coal dust. In almost all of the explosions initiated by gas, it was indicated that the ventilation current had been interrupted or was inadequate or was not directed properly; in 11 instances it was found that inspection was inadequate and that the hazard of gas was ignored or treated as unimportant

Two of the gas explosions occurred in mines considered by the operator and the State to be nongassy. As in numerous cases in the past, these occurrences call attention to the fact that essentially all coal mines are potentially gassy, and coal mines that have operated for years without encountering explosive gas may become gassy unexpectedly. The mining laws of practically all of the States are wholly inadequate with respect to the classification of mines as gassy or nongassy; as a result, many mines are operated on a nongassy basis when it is known that they are, in fact, gassy, in that explosive gas is known to be given off.

Instances still exist of miners' resistance to the introduction of permissible cap lamps and of violation of rules against smoking, as well as opposition to rules or regulations against smoking in mines. Operators have opposed and continue to oppose restrictions against open-type electric equipment and requirements for increased ventilation and tests for gas. Similarly both miners and operators have opposed the replacement of black blasting powder or dynamite with permissible explosives or they use permissible explosives unsafely. In the face of the record of explosions and fires from these causes year by year, opposition to reasonable safe procedures is difficult to understand, and it is evident that much educational work remains to be done.

Three of the dust explosions that occurred during the year were caused by blown-out shots; in each case the explosive was black powder shot "on the solid." Another dust explosion was initiated by detonation of an open box of explosives and detonators when a short-circuited live wire fell into the box; another disaster was caused by the use of permissible explosives in a manner to destroy their safety. The use of nonpermissible explosives and unsafe methods of blasting in coal mines with any type of explosives will continue to breed explosions and fires, even though in some cases the resulting fatalities may be limited by liberal use of rock dust.

8. The frequency of explosions during the past year (17) decreased as compared with the previous year (21). The average number of deaths per explosion last year was 9.1 compared with 2.8 in 1946 and 4.5 for the preceding 18 years. The high severity rate for 1947 is due largely to the small number of nonfatal ignitions reported and to the great loss of life in disasters which did occur.

9. The 17 explosions and 154 deaths during the fiscal year 1947 occurred in 8 States; 18 other coal-producing States are not known to have had explosions. The anthracite region of Pennsylvania had 4 explosions with 27 deaths in the fiscal year, breaking an excellent record of almost complete avoidance of major disasters for several years.

10. The facts brought out by a study of the explosions that occurred during the past year emphasize the importance of allaying coal dust at its source in bituminous-coal mines. Coal dust was responsible for or was involved in 7 of the 17 explosions causing 125 deaths. In all of these cases, adequate rock dusting very probably would have saved many lives and in some cases possibly it would have prevented the explosion. In at least one other case, rock dust did prevent propagation of a gas explosion. Fine dust is produced in increased quantities by mechanical mining hence the need for allaying the dust at its source, where rock dust cannot be advantageously applied. Fine coal dust is a hazard to health as well as a cause of explosions; and every feasible means should be employed to suppress it, chiefly by the use of water or wetting agents or both at or near working faces as well as at loading points and along haulage roads, conveyor belts, etc. This practice, now used extensively, should be applied freely in all places in all mines where dust is made.

11. Rock dust was reported to have been used in only 5 of the 12 bituminous-coal mines in which explosions occurred during the past year; effective rock dusting was done in 2 of these mines, but in the other 3 it had little or no effect on limiting the explosion. No widespread explosions occurred in any of the hundreds of well-rock-dusted mines in the country, which may be

considered evidence of the value of this treatment in reducing the incidence of explosions in mines where rock dusting is thorough.

12. During the fiscal year 1947, 16 coal-mine fires were reported, compared with 19 in 1946 and an average of 20 fires annually for the preceding 17 years. There were no deaths from fires in 1947, compared with 1 in 1946 and an average of 11 for the 17 previous years. Two underground fires in small metal mines were also reported, neither of which caused any fatality.

13. Of the 18 fires listed for the fiscal year, 5 were of electrical origin, 3 were caused by open lights or smoking, and 1 by explosives; 9 were of miscellaneous origin, such as spontaneous combustion (3), belt friction (1), surface fires (2), hot metal from cutting with torches (2), and rekindling of an old fire (1).

14. The marked decrease in the frequency and severity of mine fires in the last 2 years may indicate the control that is possible when more or less concerted attention is given the problem, as was done after the series of disastrous fires in 1942, 1943, 1944, and 1945. The hazards have certainly not been eliminated, and suitable measures for protection of lives and mines are to be found in only a fair percentage of mines, yet the results have been better than would have been expected 2 or 3 years ago. It is reasonable to hope that the good record of the past 2 years will become the normal experience, even though practically every underground mine continues to have numerous fire hazards.

Most coal-mine fires have been of electrical origin, and many of these continue to be caused by the trolley circuits. The answer to this hazard has not been determined, and the search for a solution should continue without waiting for some further outbreak of serious fires to compel attention. Fires usually cause heavy property damage and loss of production, once they get beyond incipient stages, and require considerable extra-hazardous effort in attempts to extinguish or control them; loss of life may be heavy, often in circumstances where such an eventuallity has seemed most remote. The potential hazard of fire in any mine is always serious, especially in coal mines, because a fire can precipitate an explosion. The definite fire hazard in the majority of mines should be recognized, and every feasible precaution should be taken to prevent fires. Also, plans should be placed and maintained in effect to handle fires quickly and safely if they occur, with equipment and materials ready at hand as far as can be foreseen. Underground employees and officials should be instructed in procedure to follow, particularly where they may be trapped behind a mine fire.

This circular was compiled in the same manner as those of earlier years (see Information Circulars 6178, 6419, 6540, 6680, 6819, 6870, 6761, 6927, 6986, 7048, 7092, 7136, 7208, 7274, 7330, and 7359) and embodies only facts revealed by investigations of field employees of the Health and Safety Branch of the Bureau of Mines. The Bureau of Mines attempts to obtain information concerning every explosion and most of the fires in mines of the United States. Although some of the less destructive mine explosions and fires may not have been brought to the Bureau's attention early enough to permit investigation, fairly complete details are obtained of almost all mine explosions or fires in which more than one life has been lost or in which considerable property is damaged; therefore the information in these publications is relatively complete.